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LONG TERM SHELTERS TO AVOID HUMANITY EXTINCTION

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Abstract

It is well known that giant long period comets originating from the Oort's cloud could be the most threatening celestial bodies. The warning time could indeed be very short and the kinetic energy could be sufficient for global and durable effects on Earth, killing all life forms on the surface. Humans might nevertheless be able to survive decades in underground shelters. Based on a model used to determine the minimum number of people to survive on another planet, a classification of long terms shelters is proposed, taking all needs into consideration and also the double redundancy principle. "A" corresponds to shelters with lots of resources but a weak autonomy, and therefore a well-established limited lifetime. "B" corresponds to long term shelters with strong autonomous capacities but little margins and high risks of collapse. "C" corresponds to ideal shelters with double redundancy for every system and also for the working capacity. Thanks to a high resilience, they could last decades, eventually saving humanity from extinction. The limits of the shelters are discussed, as well as uncertainties. The risk is indeed high that some problems are underestimated and a slow but unstoppable degradation of life conditions would lead to the death of the survivals, whatever the preparation and motivation of the survivals and the category of the shelter.

1. Introduction

In a recent paper, it was shown that the risk of extinction of humanity due to the impact of a giant comet was of the order of 2.2×10^{-12} for the next hundred years [22,28]. The Oort cloud is indeed a reservoir of very large comets, on the order of 100 km in diameter, and the instability of their orbits is such that it is relatively common for one of them to approach the inner solar system, and, potentially, be on a collision course with the Earth [3,7,8,9,16, 20, 23, 37, 38]. It is important to note that giant asteroids do not pose as great a threat to the end of humanity, because when they are large, they are quickly spotted and it is possible to predict their approach to the Earth several centuries in advance [5,10,12]. However, at the present time, none of those that have been recorded are on a collision course. It is possible and even likely that such a threat will finally be realized in a few thousand or million years. However, if it does, assuming that a deviation is practically impossible given the inertia of an asteroid of this size [12,13,19,21,29], there would certainly be time to attempt the establishment of permanent bases on the Moon and Mars (if this has not already been done), thus avoiding the total annihilation of humanity and terrestrial life in general [6,15,27,31,39]. Giant long-period comets, on the other hand, are detected very late, typically close to Nepture orbit, less than ten years before a potential impact [12,13,21]. Such a delay is far too short to intercept, deflect, or attempt to colonize another planet. In this case, the only solution would be to try to survive for a very long period on Earth in underground shelters [1,2,26,28,35]. This is precisely the initial context of the study presented here. The fundamental question is to know if it is possible to survive, and if so, under what conditions. To better understand the issues and difficulties, we propose to classify the shelters according to a survivability criterion, based on a model presented in a previous study [26]. Section 2 is dedicated to the presentation of the survival context. The survival model is recalled in section 3, as well as the proposed classification of shelters. The limitations and approximations of our approach are discussed in the conclusion.

2. Context of survival

We assume that a very large object, about 100 km in diameter, is about to impact the Earth and that there are only a few years to prepare to build underground shelters. The expected impact is much more energetic than the one that caused the end of the dinosaurs [11,13]. The degradation of living conditions would be much greater. Several studies suggest that the Earth could become unlivable [17,18, 30, 32, 34]. First, after the impact, there would be an astronomical amount of ejecta that would spread all over the Earth, causing fires everywhere, even in the regions opposite the impact. Extremely hot temperatures, above 100 degrees Celsius, would then be observed over the entire surface of the Earth, the ocean would boil, the atmosphere would be totally occluded for years, and then after a period that could last a decade, a slow and steady cooling would take place, leading to an interminable winter [18]. The threshold of 100 degrees being exceeded, the risk is consequently a complete sterilization and thus the annihilation of all the terrestrial animal and vegetable species, even microscopic, except for some which would be buried deeply or which would live in the depths of the oceans. Humanity would not escape this rule. However, since humanity has reached a high level of technology, with great capacities of adaptation, it is possible to build underground shelters far from the surface and to install life support systems to control the temperature, the pressure and the composition of the air, to grow plants allowing to produce food, to install energy systems, industrial systems, habitats, and all that is finally necessary for the long-term survival. Technically, the solutions exist. Given the complexity of such shelters and the short time available before impact, only small human groups could benefit. This raises the problem of selection and the number of people who could access them.

3. Long term shelters

3.1 Survival model

We propose to use a model that enabled the determination of the minimum number of people for survival in complete autonomy on another planet [27]. This model is based on an exhaustive list of technical requirements and the counting of the hours of work necessary for all the activities considered essential for survival. These activities are classified in 5 areas (see Figure 1):

d1: Ecosystem management: the main activities concerned by designing and maintaining systems for the production of appropriate gases, controlling air composition, pressure and temperature in habitable modules, collecting, and recycling water, controlling life cycles of all living organisms, processing organic wastes, growing plants for agriculture and finally producing and storing food.

d2: Energy production: the main activities linked to energy production, as well as the construction and maintenance of energy systems, whatever their nature, based on electricity, heat, fuels, batteries, etc.

d3: Industry: especially metallurgy and chemistry, the main activities are extracting, collecting and processing appropriate ores, making construction materials, manufacturing objects, and producing tools for other activities (e.g., agriculture). Industry may also be concerned in the production of glass, ceramics and plastics, as well as clothes and medicine depending on the strategic choices for survival.

d4: Building domain: The shelter will have to be designed and organized for good living conditions and optimization of the work. All activities linked to the architecture, organization (or reorganization), maintenance and construction of rooms, walls, corridors, doors, storage zone, etc. are included here.

d5: Social activities: For survival of the group, it is important to raise children and to educate them. Other fundamental human activities concern health care, organizing the work, solving unexpected problems, and making decisions. Sport, culture and entertainment activities also have to be considered to make sure that the group does not collapse due to psychological trauma.

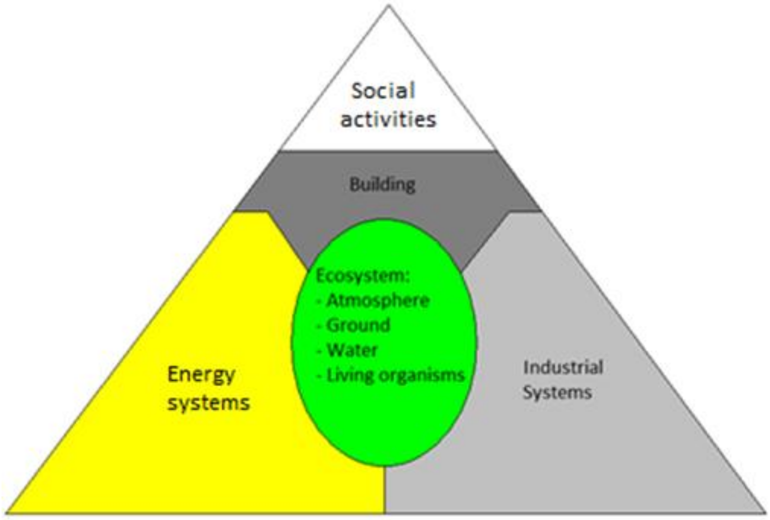

Figure 1. For survival, 5 important domains are highlighted.

The model is based on the concept of « sharing factor ». It is defined as follows: Given a time requirement per individual A_1 to accomplish an activity for the needs of 1 individual and A_n the time requirement per individual to accomplish the same activity for the needs of n individuals, the sharing factor S(A, n) is mathematically defined by:

$$S(A,n) = A_1 / A_n \quad (1)$$

For instance, if two hammers can be shared by ten individuals, then there is no need to build more than two hammers as long as the number of individuals is less than ten. As a consequence, the time spent per individual to build and maintain hammers is five times less for ten individuals than for one individual. For n=ten individuals, the sharing factor is therefore five. Once the sharing factor is known, it is possible to check if the time available for working is sufficient to implement all activities. As proposed in [27], equation (2) can be used to check if the required individual annual working time is less than the available individual working time. If not, it means that the group of people is too small to implement all required activities for survival in the shelter.

$$\sum_{i=1}^{i=k_1} \frac{r(a_{1,i})}{s(a_{1,i},n)} + \sum_{i=1}^{i=k_2} \frac{r(a_{2,i})}{s(a_{2,i},n)} + \sum_{i=1}^{i=k_3} \frac{r(a_{3,i})}{s(a_{3,i},n)} + \sum_{i=1}^{i=k_4} \frac{r(a_{4,i})}{s(a_{4,i},n)} + \sum_{i=1}^{i=k_5} \frac{r(a_{5,i})}{s(a_{5,i},n)} < 2740 \text{ h} \quad (2)$$

Where:
- $r(a_{j,i})$ is the individual annual working time requirement to run activity $\boldsymbol{i}$ in domain $\boldsymbol{d_j}$.
- $s(a_{j,i}, n)$ is the sharing factor for activity $\boldsymbol{a_{j,i}}$ with **n** the number of individuals
- k_1 to k_5 are the number of activities for domains $\boldsymbol{d_1}$ to $\boldsymbol{d_5}$.

- 2740 h: available annual working time, taking nights and non-productive people into account (derived from [27])

3.2 Classification of shelters

Based on the previous model, it is possible to make a classification of shelters. First of all, it is not clear how much time has to be spent into the shelters before coming back to the surface. If it is not too long, on the order of two to three years, a possible and viable option would be to store lots of resources and to rely on them for survival, knowing in advance that the lifetime of the shelter would be limited. This is what we call shelters of Category A. For example, it is possible to avoid agricultural production if there is sufficient dehydrated food. Nevertheless, when it is possible to come back to the surface, the atmosphere should be breathable and agriculture would have to be started straight away in order to produce food for the next months. Such a strategy would be easy to implement, but the success would strongly depend on the evolution of environmental conditions on the surface of Earth. If a long-term autonomy of the shelter is required, this kind of shelter would be inappropriate.

If the shelter is designed for the long-term survival of the group, that is if it is possible to implement all activities required for survival and if equation (2) holds, it does not mean that survival is ensured, because there are many possible reasons for a collapse, see Figure 2 for possible causal chains.

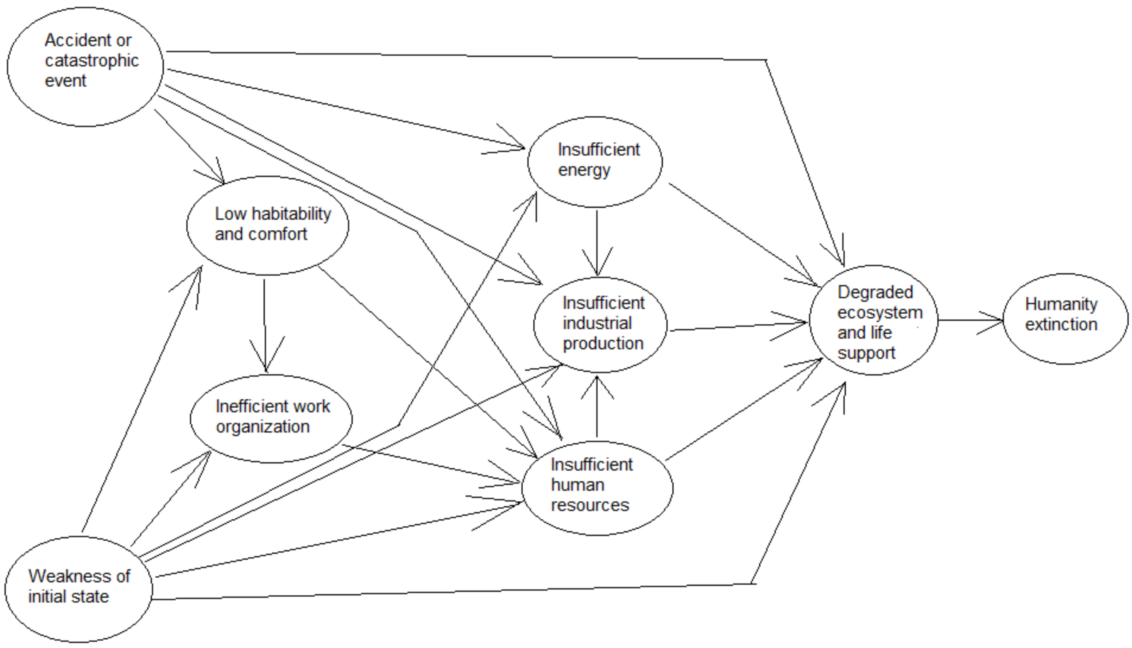

Figure 2. Causal chain of humanity extinction. Many factors could lead more or less directly to a degraded state of the life support systems inside the shelters and finally to the extinction of humanity.

It is nevertheless difficult to determine the exact cause of the failure. It is proposed here to consider two categories of shelters depending on risks estimates. In complex domains such as aviation or astronautics, in order to reduce the risks, all systems are tripled (double redundancy). The same approach can be taken here. Once the needs are determined, the systems shall be designed so as to be able to produce 3 times these needs. In addition, the systems also are resources of the shelter. Therefore, the industry shall be designed in order to be able to build or repair three times more systems than the minimum required. Also, considering equation (2), it is suggested that the available annual working time must be three times the required annual working time. By doing so, we can further split the shelters into two categories:

- Shelters of category B may allow long-term survival, but do not respect the double redundancy principle and, to some extent, present a certain risk of failure.
- Shelters of category C allow long-term survival, and do respect the double redundancy principle. The long-term survival is not sure, but an important resilience exists. If an important failure occurs for an important system, as there is redundancy, there is no immediate threat to survival. In addition, another backup system exists that allows time to repair or adapt to the situation without being frightened by the loss of the first backup system.

4. Conclusion

A method has been proposed to determine the category of shelter and its resilience for long-term survival. The triple redundancy principle allows some margins and suggests that survival of humanity after the impact of a giant comet could be possible with a shelter of category C. However, we did not discuss here the details of the technical specifications. For instance, there should exist in the shelter an energy production system that would supply electricity to other systems, but what would be the energy source? Without solar energy, a nuclear power plant might be the solution, but it would very difficult to build such a plant in the very limited time before the impact. It would probably also be required to add industrial systems to produce iron, glass, plastics, etc., but as the size of the shelter would be rather limited, so would be the amount of available resources. Recycling resources could be a solution, but it could be very difficult to determine in advance the recycling rate and the processes that have to be implemented. In other words, it might be almost impossible to determine the exact specifications of a category C shelter, especially given the short time available before impact, without time for tests and simulations. In addition, the requirements of such shelters could be unpractical, for instance if calculations suggest the excavation of several cubic kilometers of rocks and the construction of a huge underground city for a group of one million people. Complementary studies are required to better understand the limitations and provide a better estimate of the risk of extinction [4,33,36].

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